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A MORPHOUS SEMICONDUCTORS

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SUMMARY

Direct measurements of the isothermal compressibility have been made to complement the adiabatic compressibility determined acoustically. The heat capacity ratio $\gamma \equiv C_p/C_v$ is near unity. Acoustic determinations of the glass transition are being made using a device described in the previous semiannual report. The laboratory has been moved to a new building.

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NARRATIVE

During the past quarter the Department of Physics has moved from its 40-year-old building to a large new building which it shares with the departments of Mathematics and Astronomy. The laboratory for work on amorphous semiconductors has been moved into a large room on the eleventh floor of the new building. The first part of the move was made in early June and the last part in late August. During the months of June, July, and August, parts of all experiments were in both buildings and efficiency was extraordinarily low. All of the apparatus has now been installed and is operating. The increased space and improved facilities allow a new efficiency which should soon overcome the time lost during the summer.

Two different experiments have yielded useful data during the past six months. The first involves direct measurement of the sample volume change as pressure is increased. The second involves acoustic observations of the glass transition. Each will be discussed below.

We are measuring the isothermal compressibility as a supplement to the acoustical work on the sound velocity and the compressibility of the chalcogenide glasses. In the Ge:Te:As system, the compressibility has been determined from direct measurement of the change of the length of the sample under hydrostatic pressure.

The length of the sample was monitored by a linear variable differential transformer (LVDT),¹ a linear transducer, which was placed inside the high pressure system. The LVDT measures the position of a special magnetic core due to the core's effect on the mutual inductance of the two secondary pickup coils with respect to the primary coil. The core of the LVDT is coupled to a plunger which is held against the sample by a small spring, as shown in Fig. 1. The LVDT is held firmly in place against a stop by a spring. As the sample changes length

due to its compression under pressure, the LVDT measures the relative change in dimensions of the sample and the sample holder. Figure 2 shows the data obtained for the measurement of $\text{Te}_{15}\text{Ge}_3\text{As}_2$. Unfortunately the interpretation of the data is subject to question due to the problems of calibrating the system to account for the compression of the sample holder and the LVDT itself. Calibration runs were made on single crystal NaCl and quartz glass. The compressibilities of these materials are not very close to that of $\text{Te}_{15}\text{Ge}_3\text{As}_2$, so further calibration runs are planned on single crystal KBr, KI, KCl which cover a range of compressibilities near that of the chalcogenide alloy glasses.

The change (Δl) in the zero pressure sample length (l_0) can be used to calculate the volume change ΔV (defined as a positive quantity) in the zero pressure sample volume (V_0) by the approximation

$$\frac{\Delta V}{V_0} = \frac{3\Delta l}{l_0}$$

Compressibility K_T is defined as the following

$$K_T = -\frac{1}{V} \left(\frac{dV}{dP} \right)_T$$

where P is the pressure and V the sample volume at that pressure.

The experimental data can be fitted to a polynomial by a least squares technique. Then the compressibility can be calculated by

$$K_T = \frac{1}{\left(1 - \frac{\Delta V}{V_0}\right)} \frac{1}{\lambda P} \left(\frac{\Delta V}{V_0} \right)_T$$

Unfortunately there is a basic difficulty in this procedure. The coefficients in the polynomial fit to the data are directly related to the compressibility and its derivative with respect to pressure. The coefficients depend on the power of

the polynomial to which the data is fitted.² It may be necessary to fit the data to the Murnaghan equation, as suggested by Anderson,³ to calculate the compressibility:

$$P = \frac{B_0}{B_0'} \left\{ \left(\frac{V_0}{V} \right)^{B_0'} - 1 \right\}$$

where B_0 is the isothermal bulk modulus extrapolated to zero pressure:

$$B_0 = - V \left(\frac{\partial P}{\partial V} \right)_T \text{ as } P \rightarrow 0$$

and B_0' is the pressure derivative of the bulk modulus.

Resolution of the difficulties in both calibration and in the choice of fitting parameters is to be expected when measurements on the alkali halide crystals are complete. Direct measurements involving the use of a LVDT inside the pressure vessel do not seem to have been attempted previously.

Amplitude measurements have been made of 10 MHz waves reflected from an interface of fused quartz and sample material as a function of temperature.⁴ A significant change in reflected amplitude is seen in the region of the normal T_g , and an even greater change is observed at a temperature greater than T_g which corresponds to a "pseudo glass transition." This pseudo glass transition occurs when the period of the ultrasonic wave is shorter than the relaxation time associated with structural changes.⁵

A typical plot of reflected amplitude vs. temperature is shown in Fig 3; measurements under pressure reveal similar curves.

As yet, consistent quantitative data have not been obtained due to the several factors which influence the exact shape of these curves, such as, the nature of the bond between transducer and quartz and between quartz and sample. The heating rate, too, has a large influence on these curves.

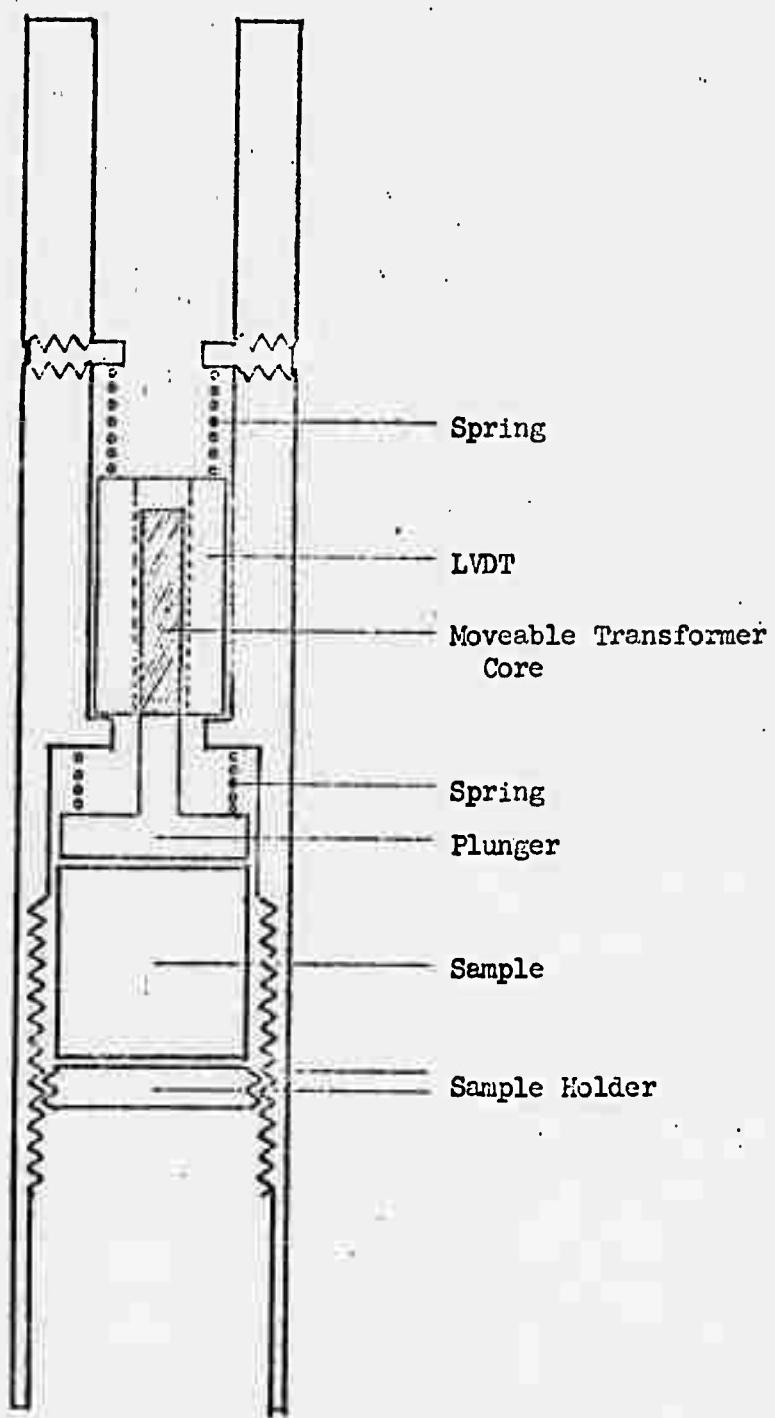


Figure 1

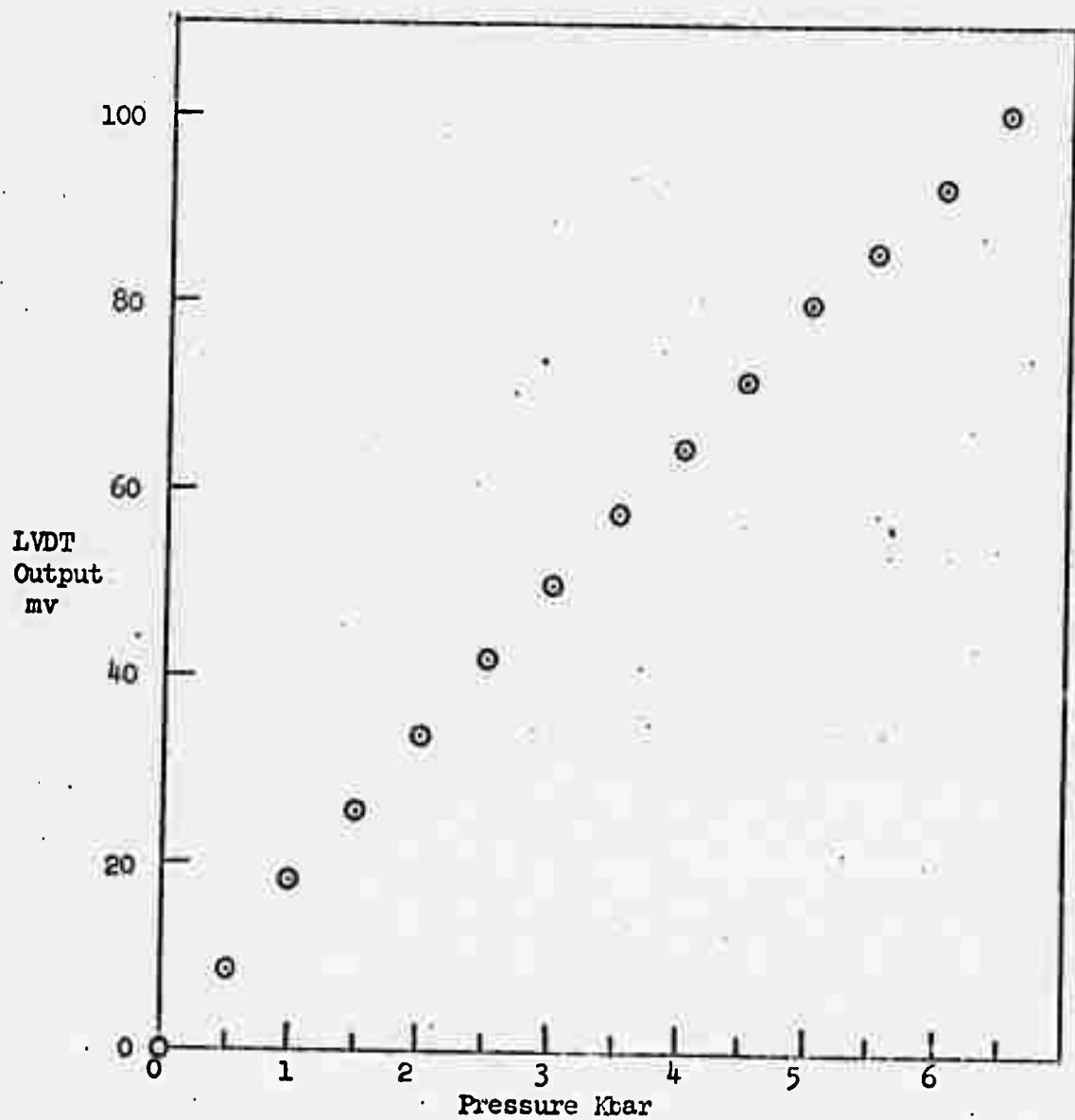


Figure 2. Change in Sample Length (LVDT Output) with Pressure for $\text{Te}_{15}\text{Ge}_3\text{As}_2$

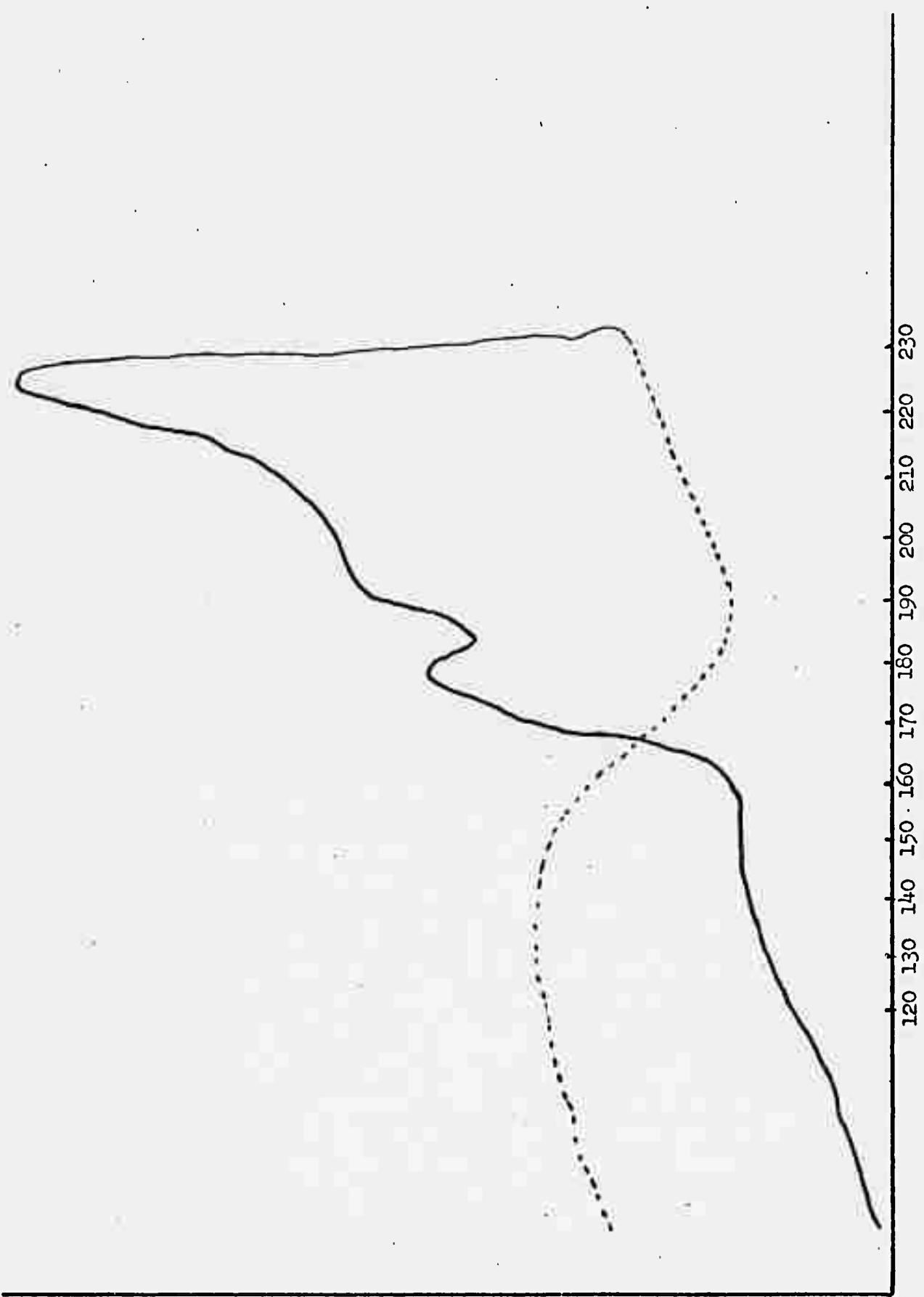


Figure 3

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